Computational Modeling of the Target Mounting Stalk in Direct-drive Implosions

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63rd Annual Meeting of the American Physical Society
Division of Plasma Physics
Pittsburg, PA
8 – 12 November 2021
Summary

The effect of the mounting stalk on direct-drive implosions is being explored in 3-D HYDRA simulations

• Both experiment and simulations† indicate direct-drive implosion performance is adversely affected by the presence of the mounting stalk.

• We present here the first 3-D, full-sphere simulations with a fully 3-D laser ray trace treatment of direct-drive implosions including the stalk.

• The stalk is found to degrade the target yield in a mid-adiabat ($\alpha = 5$) implosion by 15%.

Collaborators

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Directly-driven cryogenic targets are positioned and held in place using a target mounting stalk attached to the capsule. Capsule radius for OMEGA cryo shots is typically 430 to 510 μm.

*Image courtesy D. Harding, M. Bonino, and D. Wasilewski*
The target positioning stalk introduces implosion nonuniformity through both a mass perturbation and laser shadowing.

Does stalk, glue, or ablator material get entrained into the hot spot?

Is the stalk shadowing significant? Does the stalk significantly affect CBET*?

*Cross-beam energy transfer
The effect of the mounting stalk was simulated for a high-performing OMEGA cryogenic implosion (shot 90288)

17 μm diameter SiC stalk

478.8 μm

430 μm

Glue spot and CBET are not currently yet being modeled

Grid is finer in theta near the stalk

This shot has been repeated several times and shown robust yield, making it a good choice for study
The implosion is modeled including the following physics and features

- 3-D laser ray trace modeling all beams individually with inverse projection noise reduction algorithm†
- $4\pi$ solid angle simulation with no symmetry assumptions
- Flux-limited Spitzer thermal conduction with variable flux limiter tuned to match 1-D LILAC simulations which included CBET and non-local thermal conduction
- LEOS equation of state
- Multi-group radiation transport
- Interface tracker for subzonal resolution of material interfaces
- Full mounting stalk (no glue, yet)

† J. A. Marozas et al., APS-DPP 2006.
Stalk shadowing leads to lower overall laser absorption at $t = 0$ by up to 20% in the shadows.

Shadowing is seen clearly for the first three rings of OMEGA beams.

For comparison, peak-to-valley $\ell=10$ mode amplitude is $\sim0.6\%$. 
There is substantial blow-off plasma from the stalk, mostly sub-critical

Mass density (g/cc)

<table>
<thead>
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<th>Material</th>
<th>Mass Density (g/cc)</th>
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<td>DT gas</td>
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<td>DT ice</td>
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$t = 1.15$ ns
CR = 1.3

Mass density
Materials
There is substantial blow-off plasma from the stalk, mostly sub-critical.

- Refraction of laser light around the stalk blowoff material appears important.
- Stalk material does not get entrained into the capsule.
The stalk shadows are imprinted onto the capsule surface.

At $t = 1.15$ ns:
- Stalk
- Isodensity contours at $\rho=1.2$ g/cm$^3$
- Diameter: $760 \mu$m

At $t = 1.3$ ns:
- Location of beam shadows
By peak compression, the stalk shadowing features are prominent at mid densities, but the hot spot is still largely intact.

Neutron yield is reduced by ~15% due to presence of the stalk.
Future work

• Include the glue spot
• Include cross-beam energy transfer (CBET)
• Investigate interaction of target offset with the stalk with and without CBET
• Investigate ice features near the stalk
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- We present here the first 3-D simulations with a fully 3-D laser ray trace treatment of direct-drive implosions including the stalk.
- The stalk is found to degrade the target yield in a mid-adiabat ($\alpha = 5$) implosion by 15%.